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THESIS

PERFORMANCE ASSESSMENT OF THE TACTICAL NETWORK ANALYSIS AND PLANNING SYSTEM PLUS (TNAPS+) AUTOMATED PLANNING TOOL FOR C4I SYSTEMS

by

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The Joint Staff established the Tactical Network Analysis and Planning System Plus (TNAPS+) as the interim joint communications planning and management system. The Marines Command and Control Systems Course and the Army's Joint Task Force System Planning Course both utilize TNAPS+ to conduct tactical C4I network planning in their course requirements. This thesis is a Naval Postgraduate School C4I curriculum practical application of TNAPS+ in an expeditionary Joint Task Force environment, focusing on planning tactical C4I system networks based on a case study of Exercise Tandem Thrust in Australia. In addition to manual tools and historical precedents, automation software enables the C4I system integration planner to rapidly plan networks to meet user requirements during deliberate or crisis action planning efforts. System architecture products derived from TNAPS+ planning can be used at the network or nodal level and exported to Annex K Communications planning documents. This thesis presents an overview of the TNAPS+ software product, implementation and performance and reveals areas for improved performance as well as identifying other network planning tools that can be used in concert with TNAPS+.

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PERFORMANCE ASSESSMENT OF THE TACTICAL NETWORK ANALYSIS AND PLANNING SYSTEM PLUS (TNAPS+) AUTOMATED PLANNING TOOL FOR C4I SYSTEMS

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The Joint Staff established the Tactical Network Analysis and Planning System Plus (TNAPS+) as the interim joint communications planning and management system. The Marines Command and Control Systems Course and the Army's Joint Task Force System Planning Course both utilize TNAPS+ to conduct tactical C4I network planning in their course requirements. This thesis is a Naval Postgraduate School C4I curriculum practical application of TNAPS+ in an expeditionary Joint Task Force environment, focusing on planning tactical C4I system networks based on a case study of Exercise Tandem Thrust in Australia. In addition to manual tools and historical precedents, automation software enables the C4I system integration planner to rapidly plan networks to meet user requirements during deliberate or crisis action planning efforts. System architecture products derived from TNAPS+ planning can be used at the network or nodal level and exported to Annex K Communications planning documents. This thesis presents an overview of the TNAPS+ software product, implementation and performance and reveals areas for improved performance as well as identifying other network planning tools that can be used in concert with TNAPS+.

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EXECUTIVE SUMMARY

C4I systems officers are expected to analyze technical requirements and perform C4I mission planning. This task requires that system planners understand the technical requirements for interoperability and the tools designed to ensure interoperability among the military services. The Air Force's Tactical Network Analysis and Planning System Plus (TNAPS+) is a tool designed to meet the needs of the C4I systems planner. This thesis assessed the utility of using TNAPS+ software to plan and manage a theater-level command and control system based on a case study of Exercise Tandem Thurst-97 held in Australia.

An after action report by the MITRE Corporation regarding communications support rendered during Desert Shield/Desert Storm highlighted the absolute requirement for the military services to start using automation programs in their network planning processes. Manual methods for planning communications systems are slow and error-prone, and do not ensure interoperability among the various suites of equipment and the different services. Software programs are required to automate the planning processes so that equipment strings can be planned with technical configuration parameters assured. TNAPS+ offers both network and nodal planning capabilities with military and commercial equipment databases for deliberate or crisis action planning scenarios.

After Desert Storm, the Joint Staff declared TNAPS+ the interim joint standard for network planning and control. As of June 1999, it is still the joint standard and is used extensively at the military services Command and Control System courses. The software offers the planner the ability to tailor a database of communication equipment, assign units and determine site locations to meet emerging operational requirements. Once the operational database is configured, the C4I systems integrator can start planning the communications and information systems support modules to include: circuit, message,

transmission and data networks. In this Tandem Thrust case study, all four network modules were developed and assessed by the student planning groups.

Many by-products of the planning process can be derived and exported from the TNAPS+ software that are part of any Annex K (Communications Plan) to an operational order. These include telephone directories, site multiplex plans, equipment configuration worksheets, timing diagrams, communications security plans, and many more. In addition, TNAPS+ offers an extensive communication control module that allow the network planner and Joint Communication Control element the ability to retrieve system status reports and to post network templates to the World Wide Web for review.

As with any software product, there are good features and bad. The limitations of TNAPS+ software include the inability to collaboratively plan a tactical network support plan over local or wide area network connections. It is a serial planning process, one operational database supported by one workstation. Files may be placed on a network server and retrieved but only one planner at a time can make any changes. Additionally, the TNAPS+ software does not provide any network assessment tools. The planner can not model the anticipated performance of the network given the expected user requirements, bandwidth availability and atmospheric conditions. Lastly, the Air Force Electronic Systems Command has placed the software in a maintenance mode. Updates to the software are constrained and if a user or agency wants to make any modifications, they must support the software change proposal with appropriate funding.

Other software products are available to the C4I system planner to include the United States Marine Corps' System Planning Engineering Evaluation Device, the Joint Interoperability Test Center Joint Interoperability Tool and a commercial Optimized Network Evaluation (OPNET) tool. These software tools can be used to enhance TNAPS+ planning efforts or as a stand-alone to the planning process. OPNET shows great potential to build and assess future architectures and is currently being used by the United States Army to model and simulate the 21st Century Digital Force efforts. On the horizon is the

Joint Network Management System (JNMS) which should include extensive network planning and assessment capabilities with real-time network control. The software and hardware components and application standards for JNMS are currently in development.

I INTRODUCTION

A. BACKGROUND

Lessons learned from U.S. military exercises and operations suggest that enhanced computer automation could speed up the communications system architecture planning process, require less personnel resources, provide a more accurate communications database, make more efficient use of available communications hardware and channel bandwidth, and increase the chances of successful military operations. The sophistication and flexibility of current tactical communications equipment makes the use of manual means to plan and control information networks both prone to error and cumbersome. Quick reaction and rapid crisis planning required for contingency operations cannot be adequately addressed with old-style "stubby-pencil" techniques.

B. PURPOSE

The purpose of this thesis to is provide a primer in automated planning systems for students in the Joint Tactical Command, Control, Communications, Computer and Intelligence Systems curriculum at Naval Postgraduate School. This thesis will introduce the students to planning techniques for engineering sophisticated theater-level command and control systems. Prior to discussing automated methods, a review of manual techniques will be discussed including their shortcomings. An operational context and case study (Exercise Tandem Thrust 97) will be provided for the background in planning an expeditionary Joint Task Force Command and Control (C2) system utilizing the Tactical Network Analysis and Planning System Plus (TNAPS+). An assessment of the TNAPS+ software will be made along with illustrative examples of planning products and templates. Additionally, other selected tools for designing and evaluating C2 architectures will be presented.

C. SCOPE

The scope of this thesis is on planning communications and computer systems support for Joint Task Forces in an austere expeditionary environment utilizing TNAPS+. The Commander, Joint Task Force (CJTF) will remain aboard a naval flagship. The intent is to produce an integrated System Architecture – descriptions of systems and interconnections, including graphics, providing for or supporting warfighting functions as described by the Department of Defense (DoD) Integrated Architectures Panel.

D. THESIS ORGANIZATION

Chapter II provides an overview of manual C4I systems planning methods, their features and limitations and documents the requirements to automate these functions based on operational experiences in Desert Shield/Desert Storm.

Chapter III provides background and developmental information on TNAPS+ automation software. Additionally, this chapter will provide an overview of the individual TNAPS+ planning modules and functions.

Chapter IV examines the utility of using TNAPS+ to plan system architectures in an expeditionary Joint Task Force. Command relationships, Command and Control systems, and information needlines for military operations will be taken into consideration (based on Exercise Tandem Thrust 97). Outstanding features of the software with exportable templates will be identified along with TNAPS+ program limitations.

Chapter V presents an overview of other available planning and system evaluation tools that may be used in conjunction with TNAPS+ in the development and evaluation of tactical system architectures in support of the warfighter.

Chapter VI presents a conclusion and makes recommendations for further study.

II MANUAL PLANNING METHODS FOR C4I SYSTEMS

A. INTRODUCTION

In the absence of automation tools, communication systems planners must resort to manual techniques for estimating and planning communication requirements. These techniques may include: Structural Analysis, User-Stated Requirements, Traffic Flow Experience and Rules of Thumb [Ref. 1]. Each of these techniques has its strengths and weaknesses. A combination of techniques and periodic revisions will be the only way to adequately define requirements using manual methods.

B. STRUCTURAL ANALYSIS

Structural analysis includes a detailed study of force elements and the information flow needed to support the activities. It serves as the foundation for communication architecture studies and is used with automated analytical techniques. Structural analysis consists of the following steps:

- Define the general environment
- Assume a scenario that reflects the operational environment
- Analyze the functions (missions, tasks) being performed from the perspective of personnel needs and the information required to execute the plan
- Develop information flow in terms of connectivity and information characteristics
- Translate functional and information flow requirements into performance requirements

C. USER-STATED REQUIREMENTS

User-stated requirements consist of oral or written surveys of communications users to compile a database of expressed needs. This technique is an iterative process – gathering information repeatedly to estimate requirements. Once the information needlines are identified, a draft of the communication plan can be produced. The plan should be briefed to operators and reviewed many times before execution. Flexibility and adaptability is key to successful implementation.

D. TRAFFIC FLOW EXPERIENCE

Traffic flow experience uses historical data for developing requirement estimates. The planner uses data to lay out the topology of the baseline system and establish the network traffic flow. Modifications through expert input may change the projected system.

E. RULES OF THUMB

Rules of thumb involve informal, usually undocumented methods, of estimating requirements based on experience. During the force structuring process for a theater of operations, the normal procedure is to allocate resources according to force size and composition. Planners simply allocate the "normal" (rule of thumb) communications support to a unit. That allocation is usually a good starting point for a more detailed analysis.

F. DOCUMENTED NEED FOR AUTOMATION

The final communication requirement estimates and planning products will probably result from a combination of the above techniques. For many years, the procedures just described were the basis for our communication plans. The dynamic needs of the tactical communications community and the proliferation of commercial solutions

require a software package that integrates both tactical and commercial suites of equipment.

The MITRE Corporation conducted an analysis of the strategic and tactical common-user telecommunications systems performance during Desert Shield and Desert Storm (DS/DS). Their communications annex report highlighted major findings concerning the planning and control of command and control systems and recommended actions to rectify problem areas. The MITRE report reemphasized the complexity of end-to-end engineering and network management of today's communications networks. The MITRE report also states that the manual planning process and limited visibility across bounds of responsibility must give way to more automation and coordinated action, especially if implementation time is shorten and more flexible response is to be achieved. In particular, network management is a major concern due to the worldwide implementation of almost every type of commercial, strategic, and tactical system. [Ref. 2]

During DS/DS, network management was largely a manual process. And unlike in other theaters, the Defense Communications System (DCS) did not have a previously established infrastructure in-theater to allow their usual procedures to work the strategic/tactical management process. The usual procedure of defining strict boundaries with limited interfaces and configuration visibility between them was found to be inadequate due to the number and variety of communication connections.

The MITRE report discussed that most of the remedies to improve the system planning and control of joint telecommunications systems, which are constructed and managed under the dynamics and stress of contingencies, lies in coordinated implementation of automated tools to assist personnel trained in this environment. Several efforts have been under way to do this. Each service and agency has been developing automated tools to improve network planning and control capabilities. This thesis concentrates on the use of the Air Force product, TNAPS+, which is the designated interim joint standard. Other automation tools will be briefly described in a later chapter. The

MITRE report concluded that coordinated exploitation of automated tools in areas of system planning and control must be done and in an integrated manner.

III TACTICAL NETWORK ANALYSIS AND PLANNING SYSTEM PLUS (TNAPS+)

A. INTRODUCTION

TNAPS+ is a Windows-based desktop planning and control system that allows the communications planner to rapidly plan a major communications operation incorporating circuit switch, message switch, transmission, and data components. It covers all TRI-TAC equipment and widely used state-of-art commercial equipment (IDNX, FCC-100, routers, switches, hubs, etc.). The system will also assist in the development of specific equipment parameters (worksheets and crew assignment sheets) to support these networks. The resulting database can then be used by the controllers (network and equipment), with program software assistance, to monitor, control, and reconfigure the networks based on the evolving battlefield situation. The result will be a communications capability more responsive to the C2 needs of a rapidly initiated and evolving wartime operation that takes maximum advantage of available sophistication built into today's communication equipment. [Ref. 3]

B. DEVELOPMENTAL HISTORY

TNAPS was originally developed by the 7th Signal Brigade United States (US) Army Europe, to aid in the planning of large tactical communications networks supporting Echelons Above Corps (EAC). The original TNAPS version assisted the network planner and operated primarily as a record keeping function. This program did not automatically design the network, but it did automate the planning process and eliminated or reduced the tedious and error-prone preparation of the detailed database. In this way, it allowed network planners to focus on critical network design considerations and freed them from much of the repetitive work.

The US Air Force used the US Army TNAPS program as a basis for the development of TNAPS+ to meet Air Force requirements. The objective of TNAPS+ was to supplement the original version with additional computer-assisted functions for both network and nodal planners, and meet the needs of the joint community. Recognizing this fact in 1991, the joint community choose TNAPS+ for near-term use in joint operations. The joint community determined that near-term meant four years. That term has been expanded due to lack of a suitable replacement. It is still considered the Joint Chiefs of Staff standard for planning tactical ground communications systems.

The minimum computer platform for Version 3.2 is Windows 95 (or Windows NT 4.0), on a 486/66 processor with 16 MB RAM, although a Pentium processor with 32 MB RAM is highly recommended. Additional requirements include sufficient hard disk space (at least 30 MB), one 3.5" floppy drive, mouse, color SVGA monitor, and printer. The TNAPS+ software program is in a maintenance mode – minor software problems will be identified and repaired. Major revisions require external funding from a service sponsor. Program management responsibility rests with Headquarters Electronic Systems Command, US Air Force, at Hanscom Air Force Base, Massachusetts. The TNAPS+ Help Desk is staffed by Logicon Corporation. The MITRE Corporation and CEA, Inc. also provide contractor support. TNAPS+ is considered Military Critical Technology. [Ref. 4]

C. TNAPS+ PROGRAM

This section describes the TNAPS+ computer program, outlines current capabilities, and describes a process of performing tactical communications system planning and system control (SPSC) at the Commander, Joint Task Force (CJTF) level.

TNAPS+ is a personal-computer-based software tool that assists the planner to build an exercise or operation database that consists of TRI-TAC and state-of-the-art commercial equipment (routers, IDNX, etc.) and produces a series of output records describing the resulting networks and equipment configurations. The system controller can

use this database, with program support, to monitor, manage, and reconfigure in-place communications. TNAPS+ runs on the Windows environment. A small portion of TNAPS+ runs in Disk Operating System (DOS) but operates on the same database.

TNAPS+ allows tactical communications planning and control at the network level and nodal or equipment level. Network planners and controllers are responsible for planning and managing the overall network as a whole, while nodal planners and controllers plan and manage a complete database for equipment within the node and generate all necessary worksheets and crew assignment sheets. Use of one program for both levels ensures the equipment is engineered to support the overall network and that the entire database for both levels is internally consistent.

Before the start of an exercise or operation, the communications planner uses the TNAPS+ program to develop a standard database, describing the communications requirements of support units. The exercise or operations database is created from this standard database. Then the program is used to create the circuit switch, message switch, data and transmission networks from this initial database at the network level. Either table generation data entry or graphical data entry can be used to develop the networks. When using graphical data entry, the associated databases will automatically be developed from the graphic inputs. Once the networks have been defined, the program, under operator control, will use the resulting data to engineer the individual equipment. For example, the crew worksheets for the AN/TTC-42 Circuit Switch can be developed and printed out. The program also includes modules to develop Communications Security (COMSEC) key management data, create standard requirements data, and manage the files generated for each exercise or operation.

The system control module assists with network management and interacts with all databases developed by other TNAPS+ modules. It allows network controllers to maintain a near-real-time status of the overall network, enter and analyze network statistics and trends, and modify the network as required.

D. PROGRAM FUNCTIONS

This section provides a brief description of the specific capabilities resident in the TNAPS+ program and presents a logical sequence to plan a tactical communications network:

- Program Structure – The TNAPS+ Windows application allows the planner to view and plan the network by viewing the circuit switch, message switch, data, transmission and site multichannel displays simultaneously. All network elements are treated as objects and wherever the objects are displayed, the planner can apply all planning and management actions to them.

- Database Management – TNAPS+ uses the DOS directory structure and makes a separate subdirectory for each of the exercises or operations being planned and controlled. The required databases are created in each of the subdirectories. This allows the planning of more than one exercise at a time.

- Standard Requirements Development – At the heart of the planning process is the identification of user requirements. Each exercise or operation is different, but the majority of user requirements are standard and form a core of known requirements. The standard requirements are loaded into the TNAPS+ database by the planner before a specific exercise or operation is started. These are coupled with the subscriber's unit database that defines as records the types of subscriber units for the tactical network. This will append the standard or normal requirements to the exercise or operation database and deviations from the norm will be as required.

- Operational Requirements – An exercise or operation must have a database identified and created. Creation can occur in three ways: from scratch based on

the program prompts, from an old exercise or operation, or from a standard database.

- Circuit Switch Planning – Once the subscriber requirements are loaded, the network planner allocates and places nodes and sites to support these requirements and provides a responsive network. TNAPS+ design is based on the assumption that circuit switch and message switch networks are planned first. Capabilities are provided to transfer circuit switch and message switch data into the transmission network database.

- Message Switch Planning – Basic subscriber requirements for record traffic are added from the operations requirements module. The message switch network planner defines the message switch network, places message switches to best support the requirement, designs interswitch trunking and AUTODIN and SCI access, and then "homes" the subscribers. Homing refers to connecting subscribers to specific message switches in the architecture.

- Data Network Planning – The data network planner defines the data network, places routers, LAN's, NES and hosts to best support the requirement, designs data network trunking, and assigns Internet Protocol (IP) addresses.

- Transmission Network Planning – TNAPS+ uses the joint numbering system and the majority of the transmission planning functions are in a graphic mode. These can include: a network layout and circuit identifiers (CCSD, circuit routing chart and channelization). High Frequency radio nets can also be defined and included in the outputs.

- Site Multiplex Plan – TNAPS+ allows the planner to define equipment connectivity. Objects that can be planned include on-site circuits, on-site

transmission systems, switches, TRI-TAC multiplexers, AN/FCC-100, and Integrated Digital Network Exchanges (IDNX).

- System Control and Management – The system control function provides for network management and interacts with all databases developed by other TNAPS+ functions. It allows network controllers to maintain a near-real time status of the network, enter and analyze network statistics and trends, and modify the network as required. Sites, transmission links, circuits, switches, and trunks can be added, deleted, modified, or renamed.

IV EXPEDITIONARY JOINT TASK FORCE C4I PLANNING

A. INTRODUCTION

The objective of building a JTF planning application upon a Tandem Thrust (TT) exercise environment is to create a solid foundation upon which each C4I systems planner may acquire a broad understanding of C4I operational systems and the details of planning theater-level networks. The focus of this collaborative exercise is advanced Communication and Information Systems (CIS) planning details for common user networks and special subscriber terminal employment within a JTF, including external connectivity to national level systems. The automated system used to plan the C4I connectivity in this application is the TNAPS+ software, version 3.2. Examples of planning templates and other documents produced by TNAPS+ will be demonstrated and assessments provided for some of the software utilities.

B. METHODOLOGY

C4I system planners have many resources at their disposal when tasked to plan and manage the integration of diverse joint communications systems in support of joint exercises and operations. During the NPS C4I curriculum early stages, various national and service level system briefs were conducted and field trips to major communication system providers enhanced the student's knowledge of command and control systems. This capstone planning exercise ties together all the phases of the NPS graduate education and operational experiences and allows the student to participate in the planning of a theater-level network architecture supporting identified user requirements. Emphasis is placed on the practical application of systems integration at the network level and coordination among the different planning cells. TNAPS+ also provides detailed planning integration at the equipment level (nodal) but that was beyond the scope of this application.

For this student planning application, C4I system planners were divided into four major planning cells – circuit, message, transmission, and data networks. Additionally, two warfighting support planning cells were organized – Air Support and Intelligence Operations. Lastly, a Joint Communications Control Center (JCCC) cell was established to take the lead in the planning effort and to de-conflict network design problems. The JCCC was also tasked to plan the overall network timing architecture.

Before the acting JTF J-6 planning cells initiated efforts, preliminary briefs were conducted on the overall Tandem Thrust exercise to include: forces assigned, missions, Area of Operations, Defense Information Systems Network support roles, reachback requirements and many other communication support issues affecting the planning effort.

C. TNAPS+ START-UP PROCEDURES

The C4I system planner utilizing TNAPS+ must be organized in the approach to building a network architecture to support a warfighting requirement. TNAPS+ builds an operational database for the planning effort - one database per exercise/operation. All planning modules will reference this one database and the database should be tailored to meet the needs of the planning effort. For example, the C4I system planner could have a contingency database built that will include all of the forces assigned to a particular plan to include the communication information systems providers (signal units) and notional tables of equipment. All known equipment and specific technical parameters should then be entered into the database prior to building the network architectures. Once the database is built, additions, deletions, and modifications to units or equipment can occur at any time. A site plan, in which units and equipment are associated, with easy pull-down into the planning templates, is pre-established if geographic locations are known in advance. Site plans include the geo-location, units assigned, and communication support units available at each specific site.

A major drawback to utilizing TNAPS+ is the lack of real time collaboration capability. TNAPS+ software is designed for serial development – the exercise or operation C4I systems plan must be developed in a sequential fashion, normally on one TNAPS+ configured planning computer. TNAPS+ is not networked and different planning cells can not plan collaboratively over a local or wide area network. Planning data can be shared via floppy disk transfers.

D. PLANNING PREREQUISITES

In any exercise or operation, three main data sets must be provided to the C4I system planner. These include the command relationships and information flow needlines, the training or warfighting mission, and the Area of Operations (AO). Figure 1 represents the command relationships for the Tandem Thrust scenario. The command relationships are clearly annotated with solid or dotted lines and the organization chart shows all participating major units of each United States military, Maritime Prepositioning Force elements, and Coalition partners. Figure 2 shows the Area of Operations for the exercise. In this planning scenario, the AO is centered on the northeast corner of Australia in the Shoalwater Bay area. The mission for the exercise was to employ a Commander, Combined Task Force (CCTF) Headquarters and appropriate forces in a short warning, power projection, live fire and maneuver field training exercise in Queensland, Australia. The mission of the C4I systems planner was to provide theater level CIS support with reachback to national level communication systems.

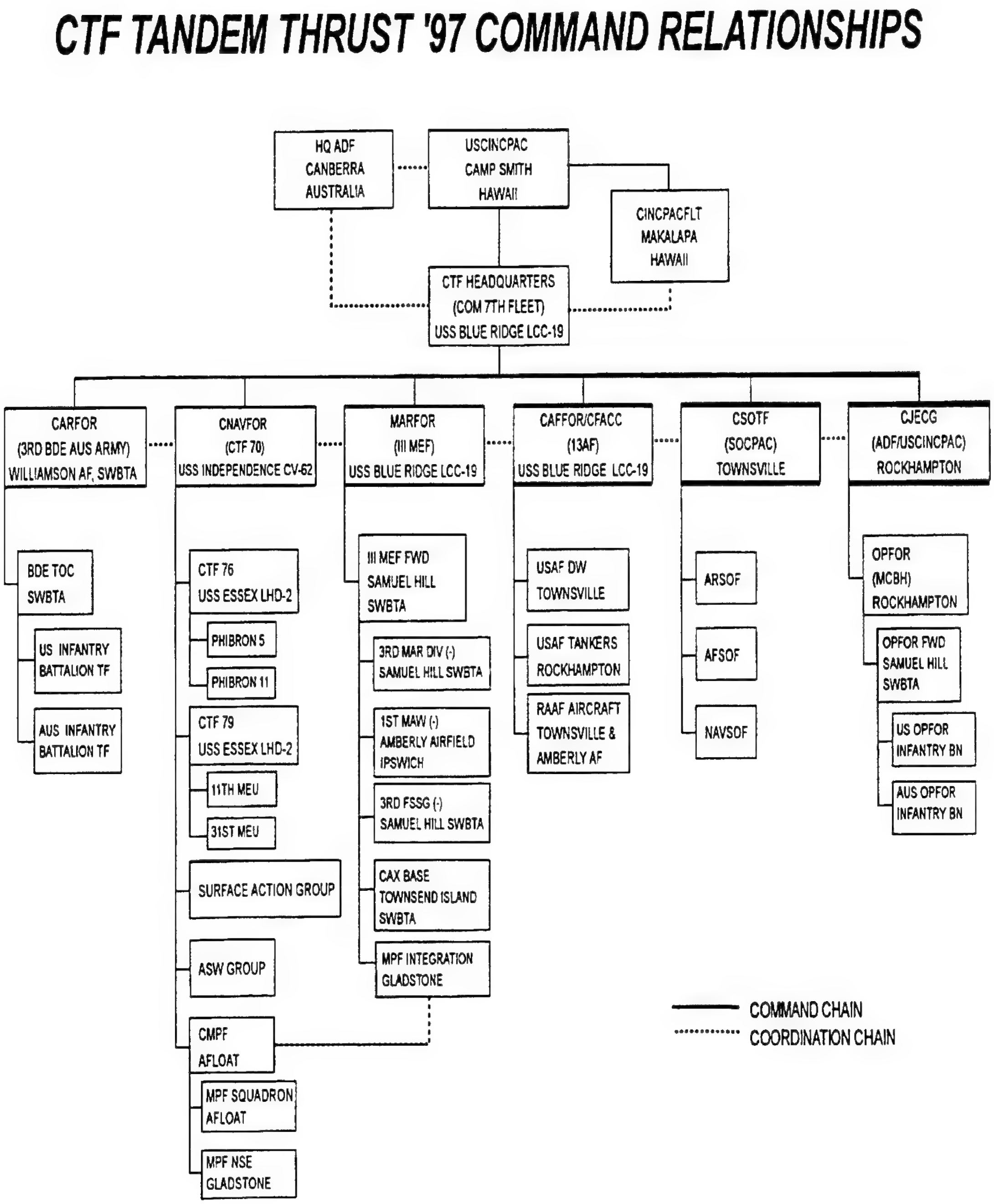

Figure 1 Command Relationships Tandem Thrust 97

TANDEM THRUST '97 AREA OF OPERATIONS (AO) QUEENSLAND , AUSTRALIA

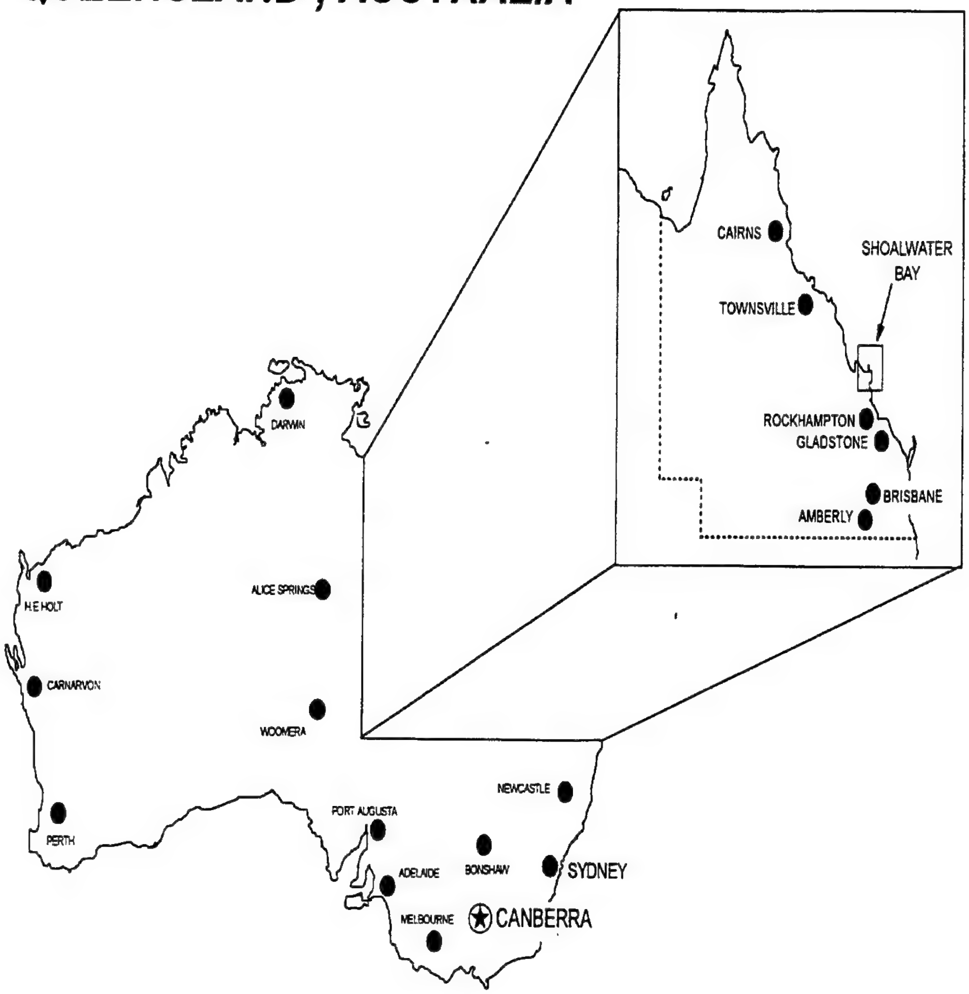

Figure 2 Area of Operations Tandem Thrust 97

Beyond just the Area of Operations though, C4I system planners need more detailed information regarding potential force locations, distances between major sites, and Naval surface platforms assigned to the exercise. Figure 3 presents more detailed information that would be required by the C4I systems planner before the network architecture templates are engineered in TNAPS+.

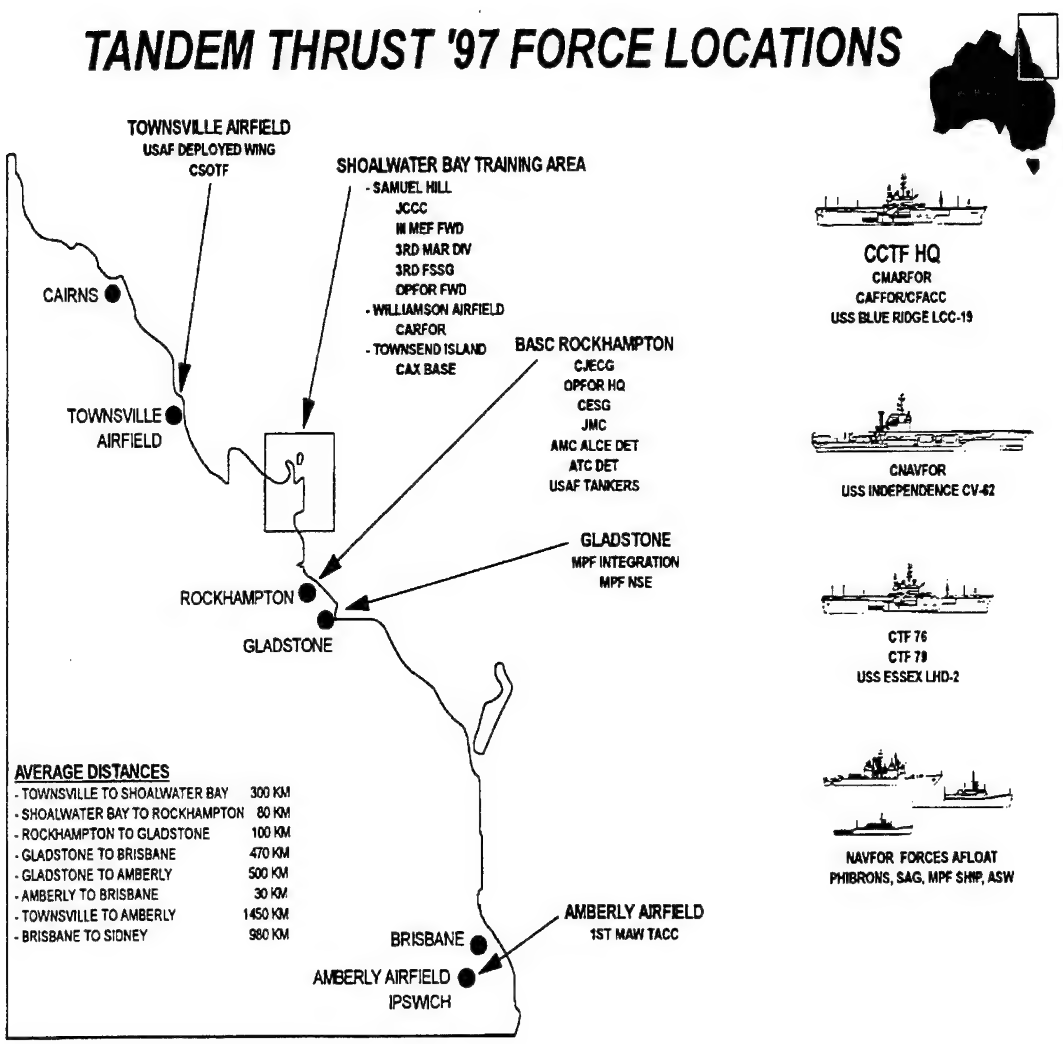

Figure 3 Detailed Area of Operations Tandem Thrust 97

E. CIRCUIT SWITCH MODULE

With the preliminary information programmed into the database, the C4I systems planner may begin to engineer the network. Normally, the circuit and message switches are associated with the site plans prior to building the transmission networks. TNAPS+ has a current inventory of the most common circuit switches in the military services and commercial circuit switches can be added to the equipment inventory list. Figure 4 is an example of tactical circuit switch template using TNAPS+ for exercise TT 97.

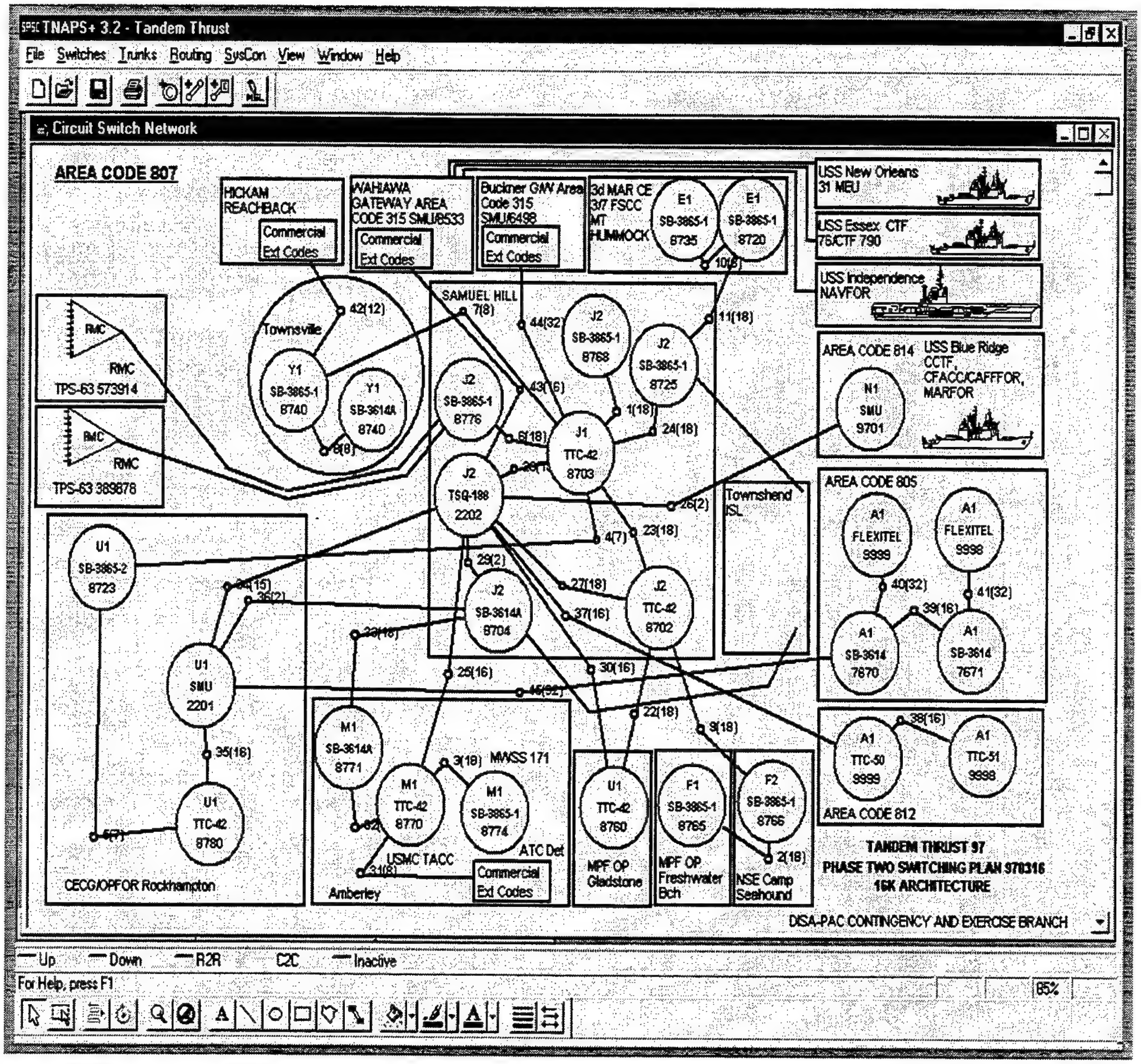

Figure 4 Circuit Switching Template Tandem Thrust 97

The circuit switch module plans the circuit switch network and produces the worksheets for individual switches. The necessary switch information includes the switch type, size, Area-Switch Codes, and site. Additionally, TNAPS+ supports both three-four (commercial-xxx-xxxx) and four-three telephone (tactical-xxxx-xxx) numbering plans and produces a telephone directory. The most common military tactical circuit switches are supported, to include: TTC-39 family, TTC-42, and SB-3865. In exercise Tandem Thrust, an extensive circuit switch plan was executed to link all forces, including ships at sea, using the Switch Multiplexing Unit (SMU). The SMU provides interoperability to TRI-TAC telephone switching standards and the units operating ashore.

F. MESSAGE SWITCH MODULE

Like circuit switching, the message switching module should be prepared prior to the transmission network planning. This module requires information including site designation, switch serial numbers, relay routing indicators, R/Y communities to be served, communication centers and their users, interswitching trunking, and AUTODIN gateways. In TT 97, and extensive array of message switches and terminals were used to deliver message traffic to exercise participants.

Figure 5 represents the US/Australian Defense Force AUTODIN Interface connectivity extracted from a TNAPS+ template. Message switching planning is extremely complex due to multiple gateways and different terminals in theater. Note the integration of coalition terminals in the architecture. Using TNAPS+, extensive message switch reports can be generated.

With Defense Message System (DMS) replacing AUTODIN, and the use of desktop computers, the message switch module in TNAPS+ may become obsolete as the services migrate to a IP-based message system using local and wide area networks. The military services are migrating away from deploying with large message switches (TTC-39, MSC-63A) due to DMS network enhancements and limited airlift.

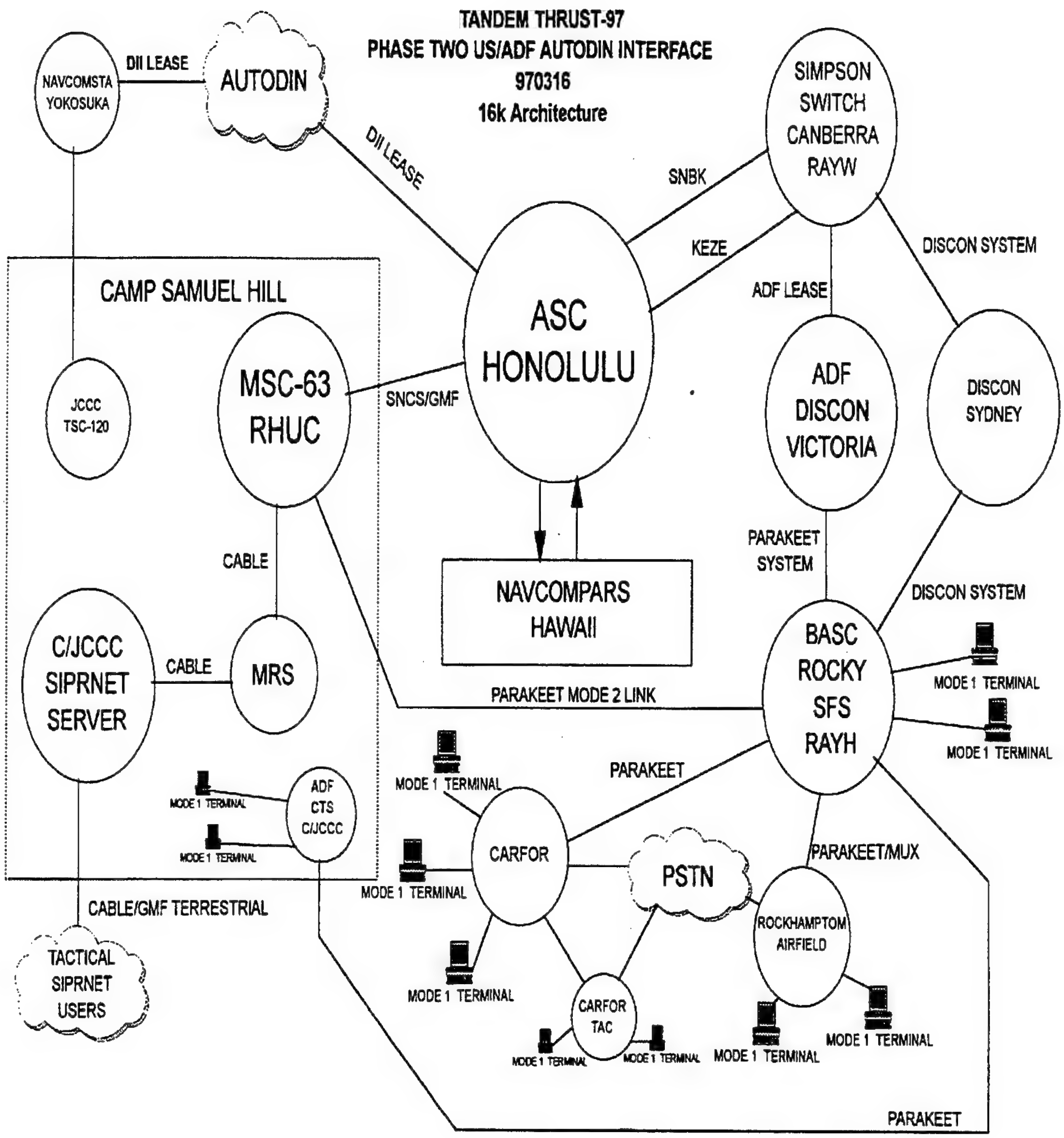

Figure 5 AUTODIN Message Switching Network Tandem Thrust 97

G. TRANSMISSION MODULE

The transmission network module is the most critical and time consuming module. After the circuit and message switching systems have been preplanned, sited and configured, the critical step of interconnecting the various switching devices and special terminal equipment together must be accomplished. This is the module that provides the detailed engineering for C4I support – satellite, switching, AUTODIN/DMS, and data communications. The transmission module allows the planner to configure satellite, terrestrial and high frequency (HF) circuits. In this exercise, all three of these transmission mediums were used to provide connectivity throughout the JTF and into the Defense Information Systems Network (DISN). For example, four super high frequency (SHF) Ground Mobile Force satellite terminals (TSC-85B, TSC-100A) accessed the DISN via Fort Buckner, Wahiawa and Hickam entry sites. Two HF terminals (TSC-120) were activated with Yokosuka and Guam as DISN terminating stations. Finally, over a dozen terrestrial ultra high frequency (UHF) multichannel terminals (MRC-142) provided high bandwidth and supplementary paths throughout the Area of Operations.

Multichannel communications planning for high bandwidth radio systems requires terminal equipment and link aggregate data rates so that the proper bandwidth, transmitting power, antenna size and multiplexing equipment can be chosen. For this planning exercise, all necessary information was provided to the planning cell from which the network templates were driven.

A key feature of TNAPS+ is the multitude of transmission systems in the equipment database so that the planner can choose and ensure interoperability within commercial and military systems. This includes multiplexing and communications security equipment. The incorporation of commercial suites of equipment is a unique capability of TNAPS+ compared to the other network planning tools available. Figure 6

shows the combined DISN satellite and HF transmission networks (SHF/HF) for exercise Tandem Thrust 97 produced by TNAPS+.

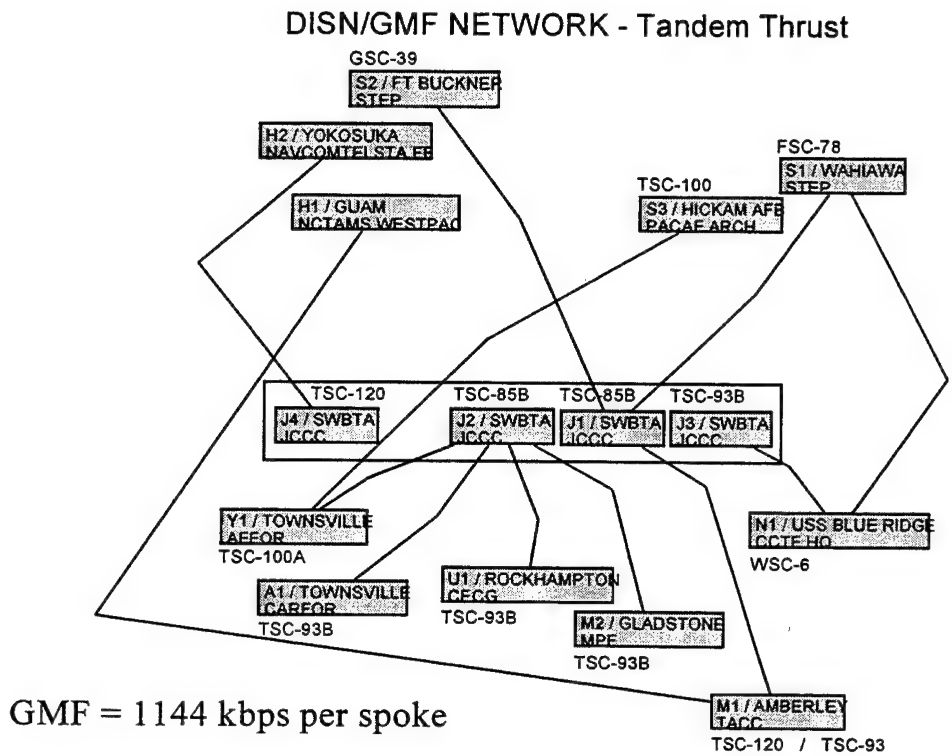

Figure 6 DISN Network Template Tandem Thrust 97

Another key feature of TNAPS+ is the ability to export network diagrams to a PowerPoint presentation. This feature can facilitate network design planning in a distributed environment prior to the activation of the networks. The diagrams can also be published in a World Wide Web format and posted to an exercise/operation web site.

An important aspect of designing the network this way is that all the circuits are configured to ride selected transmission paths and the planner can drill down through the

network clouds for more specific information. System Control elements can also view site location equipment inventories, re-configure connections and review voluminous status reports. The UHF and SHF terrestrial networks are planned in the same manner as the satellite multichannel paths. Sites are pre-configured, radio sets are selected and database circuits are added until the aggregate data rates are reached. Like the other network diagrams, the drill down capability provides the nodal operators extensive site diagrams depicting circuits, data rates, subscriber equipment, etc. Figures 7 and 8 represent UHF and SHF network diagrams derived from TNAPS+ software in support of this planning exercise.

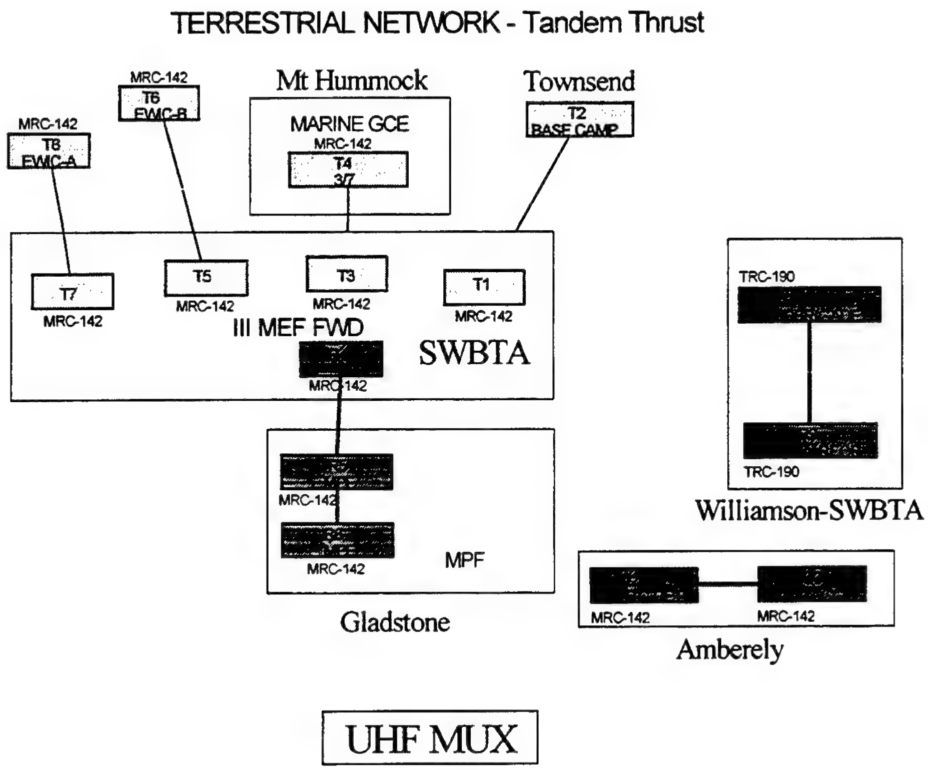

Figure 7 UHF Terrestrial Multichannel Diagram Tandem Thrust 97

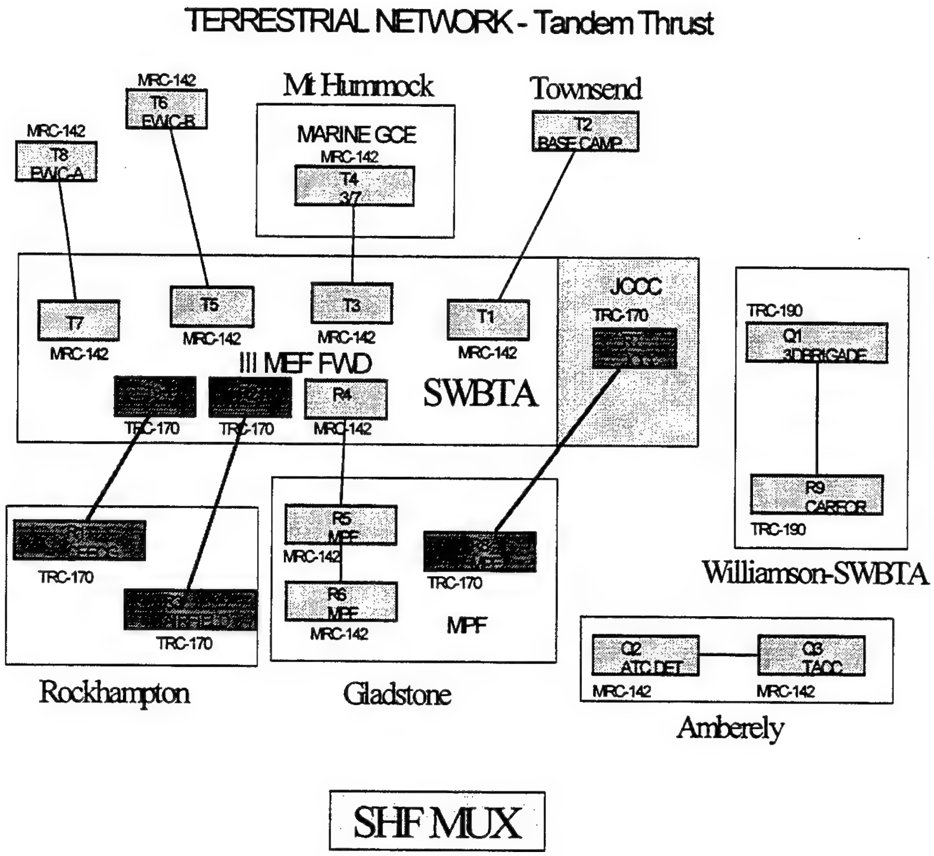

Figure 8 SHF Terrestrial Multichannel Diagram Tandem Thrust 97

The TNAPS+ software is user friendly when creating architectures. The software asks the planner for all the pertinent data when creating a node. This is conveniently listed on the screen. The software also automatically calculates link throughput capabilities (bandwidth). The Site Multiplex Plans derived from the transmission module are extensive however, they are visually difficult to comprehend and read. Overall, the transmission module has some great capabilities but shortcomings related to graphics, integration to other planning modules, and collaboration capabilities limited its total effectiveness.

H. DATA NETWORK MODULE

Perhaps the more important capability resident in the planning software today is the Internet Protocol planning utilities. In Tandem Thrust both the SIPRNET and NIPRNET played major roles in delivering information to the warfighter and support staffs. The network diagrams are incredibly complicated and only through computer automation can they be managed with any accuracy.

In TNAPS+ the data network is developed incrementally. An example of this would be creating the routers first, then creating the long haul connections, and finally, one workstation at a time on the local subnetwork level. The software allows the planner to identify types of hardware, either from the preexisting database or a custom defined data type, then connects the ports to another workstation or to a router. The program keeps track of each kind of port on each piece of hardware, as well as what kind of protocol is being used. Since there is no simulation capability, the program provides notification to the planner if there is some discrepancy between port types that are being connected.

There are many levels of complexity and details in this planning module, but one of the most useful tools was the IP calculator which facilitates the assignment process of IP addresses. However, even in this all important module, many software idiosyncrasies exist that limit the overall utility. For example, each workstation must have an IP address assigned to it; in the real world, the IP of a workstation might not be identified until later in the planning stages. Further, if a workstation IP address needs to be changed, the software requires that the workstation be deleted and re-created with the correct or different IP address. "Right click" property dialog boxes would be very useful here.

Another limiting feature was the graphical capabilities. The network diagrams become very difficult to read and de-clutter as more components are added and more icons are needed to differentiate between routers, bridges, workstations, modems, etc.

Figure 9 represents a typical data network diagram supported by TNAPS+.

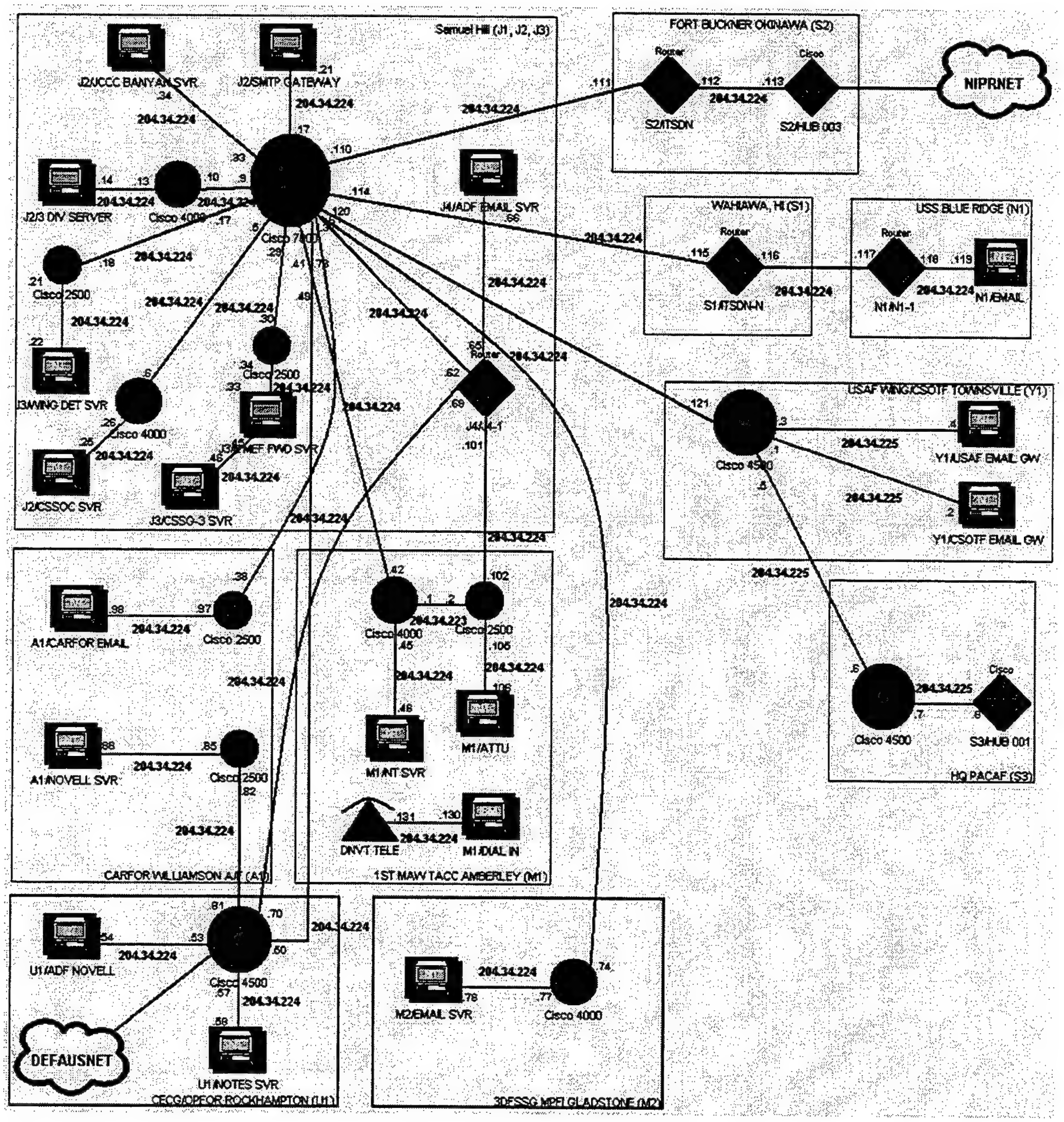

Figure 9 NIPRNET Network Diagram Template Tandem Thrust 97

I. JOINT COMMUNICATIONS CONTROL CENTER MODULE

The Joint Communications Control Center (JCCC) functional role is to serve as the senior planning agency responsible for all communications planning, installation and operation. The J-6 of the JTF designates the unit to perform JCCC duties and that unit is augmented by representatives from Defense Information System Agency (DISA) and the various military services involved in the exercise/operation. It is responsible for publishing and distributing planning documents prior to execution, to include:

- Annex K (C4I Architecture)
- SIPRNET and NIPRNET IP Addresses, Domain Name Server IP Addresses
- Network Directory
- Communication planning and coordination messages
- Communications Security Callout
- Network Timing Diagram

TNAPS+ Systems Control module can facilitate meeting all of these objectives. Additionally, the software has extensive status report capabilities. The system control pull-down menu allows for quick status checks of circuits and systems, updates to circuit switch and message switch statistics, printouts of report generation, and creation of a telephone installation priority list. Reports generation can be printed or posted to a web site.

Equipment-timing coordination and publication is critical to successful operation of TRI-TAC communications. TNAPS+ provides a tool to conduct network timing

diagramming, including all the major systems. The diagrams can be exported as briefing slides.

Examples of timing diagrams produced by the TNAPS+ system control module are shown in Figures 10 and 11. Options available in the timing module include timing source, timing mode, clock-type, and report.

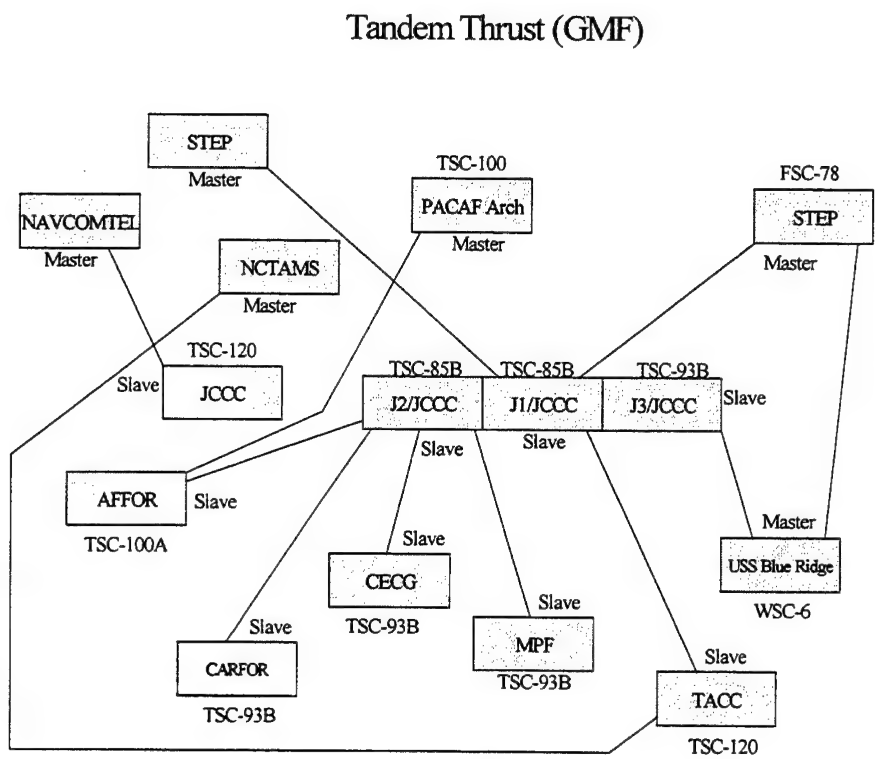

Figure 10 GMF Timing Template Tandem Thrust 97

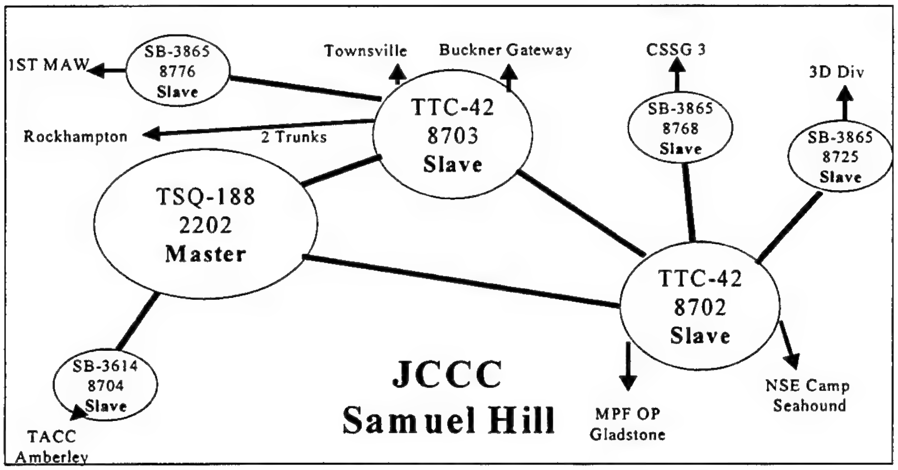

Figure 11 Swithing Timing Template Tandem Thrust 97

System control reports are an essential function of any JCCC. Figure 12 is a representative sample of a TNAPS+ system log screen. Network statistics and Reasons for Outages are also kept.

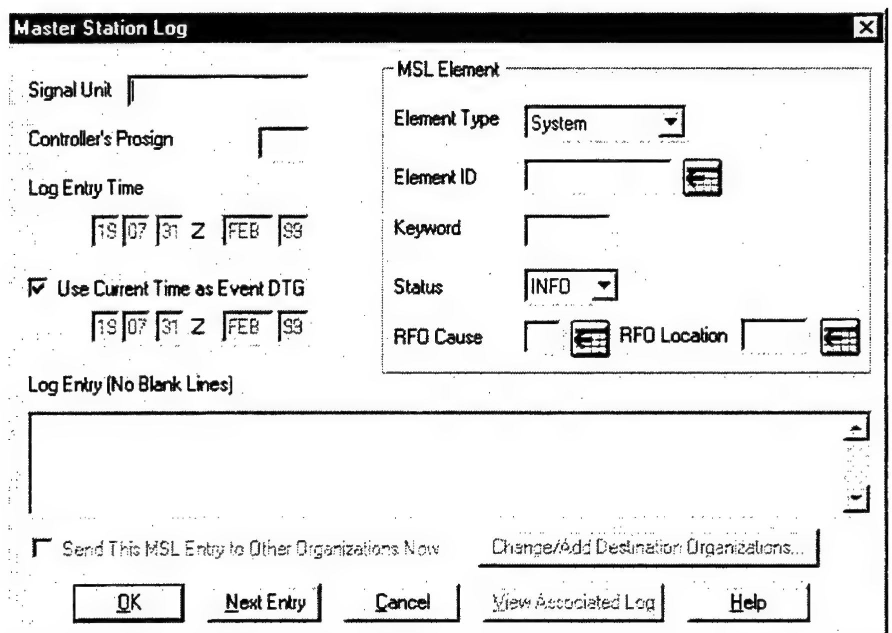

Figure 12 TNAPS+ Master Station Log Screen

V SYSTEM ENGINEERING AND EVALUATION TOOLS

A. INTRODUCTION

As stated previously, each service has initiated programs of their own to automate the systems planning and control of strategic/tactical telecommunications. There also have been numerous efforts at the Department of Defense (DoD) level. Along with TNAPS+, the DoD has developed products such as: Integrated C4I Architectures Requirements Information System (ICARIS), the Joint C4ISR Architecture Planning/Analysis System (JCAPS), the CINC Interoperability Planning System (IPS), and the Joint Decision Support System (JDSS). Each of these automated tools are described in detail in Ref 1, Chapter VII, "Requirements Planning Process." The advantage of TNAPS+ is that it incorporates military and commercial products into the integrated planning process and the derived templates are exportable to a communications plan (Annex K). Other unique tools have been developed and will be briefly described next.

B. SYSTEM PLANNING ENGINEERING EVALUATION DEVICE

The Marine Corps has developed an organic system planning and engineering program, System Planning, Engineering, Evaluation Device (SPEED). SPEED is a team-transportable, fully integrated, microcomputer-based system that supports Marine Air Ground Task Force (MAGTF) tactical communications planning. [Ref. 5] This system provides automation tools to define a tactical communication system that can be evaluated before installation. Modules of SPEED provide the following capabilities:

- TNAPS+ software tool
- Point-to-point analysis
- High-frequency analysis

- Area coverage analysis
- Guard chart analysis
- Signal/noise and signal/interference analysis
- Topographic database
- Database of basic equipment characteristics
- Revised Battlefield Electronic Communication Electronic Operating Instructions System (RBECS) software programs for CEOI/signal operating instructions generation
- Switched Network Automated Planner (SNAP) software tool

SPEED is designed to support the development, analysis, and modification of communication plans. SPEED does this by providing instant access to radio propagation and network planning tools (TNAPS+ and SNAP) on a Microsoft Windows-based system. Designed for use in both field and garrison environments, SPEED also serves as the Marine Corps' platform for RBECS software required to enable Single Channel Ground and Air Radio System (SINCGARS) radio operation in frequency hopping mode. [Ref. 6]

SPEED is a stand-alone system, intended for use by units down to the Battalion level. Data files can be shared between systems via floppy disk. Switched Network Automated Planner (SNAP) is a subset software module in SPEED (like TNAPS+) and is used to plan and engineer switched communications networks utilizing Unit Level Circuit Switches (ULCS). Through a series of user selections, inputs and software routines, the SNAP assists in planning and engineering a network and provides physical and database configuration data for ULCS equipment.

SPEED is a comprehensive automation tool for the Marines. It provides tools for point-to-point path profiling, area coverage analysis, high frequency propagation analysis, satellite planning, Position Location Reporting System (PLRS) network planning (Line of

Sight and Position Location Information studies), and ULCS network planning. Using these tools in conjunction with world data maps enables the user to plan and position communication assets. It provides the ability to rapidly evaluate the impact of modifications to transmitter/receiver locations or other physical parameters.

C. JOINT INTEROPERABILITY TOOL (JIT)

The Joint Interoperability Test Center (JITC) Joint Interoperability Tool (JIT) provides high-speed access to key interoperability information. The heart of the system is an extensive data repository featuring the JITC Lessons Learned Reports, JITC Test Reports, the NATO Interface Guide, Joint Interoperability Certification Letters, and other interoperability documents and references; as well as a high speed search engine to quickly access data. This tool provides a quick and easy on-line capability that identifies system or equipment characteristics, tested configurations, and practical "how-to" information to facilitate interoperability. [Ref. 7] Access can be provided by either the NIPRNET/Internet or SIPRNET using a web browser.

D. OPTIMIZED NETWORK EVALUATION TOOL (OPNET)

Optimized Network Evaluation Tool (OPNET) provides a comprehensive development environment supporting the modeling of communication networks and distributed systems. Washington D.C.-based MIL 3 is the sponsoring company. This breakthrough product provides network performance prediction, a sorely lacking capability in TNAPS+ and other network planning tools. OPNET can identify future bottlenecks and assist network managers in maintaining Quality of Service (QOS) levels.

The OPNET environment incorporates tools for all phases of a simulation study, including model design, simulation, data collection, and data analysis. OPNET is a vast software package with an extensive set of features designed to support general network modeling and to provide specific support for particular types of network simulation

projects. This section provides a brief enumeration of some of the most important capabilities of OPNET: [Ref. 8]

- Object oriented – Systems specified in OPNET consist of objects, each with configurable sets of attributes. Objects belong to "classes" which provide them with their characteristics in terms of behavior and capability. Definition of new classes is supported in order to address as wide a scope of systems as possible. Classes can also be derived from other classes, or 'specialized" in order to provide more specific support for particular applications.

- Specialized in communication networks and information systems – OPNET provides many constructs relating to communications and information processing, providing high leverage for modeling of networks and distributed systems.

- Hierarchical models – OPNET models are hierarchical, naturally paralleling the structure of actual communication networks.

- Graphical specification – Modes are entered via graphical editors. These editors provide an intuitive mapping from the modeled system to the OPNET model specification.

- Flexibility to develop detailed custom models – OPNET provides a flexible, high-level programming language with extensive support for communications and distributed systems. This environment allows realistic modeling of selected communications protocols, algorithms, and transmission technologies.

- Automatic generation of simulations – Model specifications are automatically compiled into executable, efficient, discrete-event simulations, implemented in the C programming language.

- Application-specific statistics – OPNET provides numerous built-in performance statistics that can be collected during simulations. In addition, modelers can augment this set with new application-specific statistics that are computed by user-defined processes.

- Integrated post-simulation analysis tools – Performance evaluation, and trade-off analysis requires interpretation of large volumes of simulation results. OPNET includes a sophisticated tool for graphical presentation and processing of simulation output.

- Interactive analysis – All OPNET simulations automatically incorporate support for analysis via a sophisticated interactive "debugger."

- Animation – Simulation runs can be configured to generate animations of the modeled system at various levels of detail and can include animation of statistics as they change over time.

- Application Program Interfaces (API) – As an alternative to graphical specifications, OPNET models and data files may be specified via a programmable interface. This is useful for automatic generation of models or to allow OPNET to be tightly integrated with other tools.

As a result, OPNET can be used as a platform to develop models of a wide range of systems. Possible applications include:

- Standards-based LAN and WAN performance modeling – Detailed library models provide major local-area and wide-area network protocols.

- Internetwork planning – Hierarchical topology definitions allow arbitrarily deep nesting of subnetworks and nodes. Large networks are efficiently modeled.

Scalable, stochastic, and/or deterministic models can be used to generate network traffic.

- Research and development in communications architectures and protocols – OPNET provides extensive support for communications-related applications.

- Distributed sensor and control networks – OPNET allows development of sophisticated, adaptive, application-level models, as well as underlying communication protocols and links.

- Resource sizing – Accurate, detailed modeling of a resource's request processing policies to provide precise estimates of its performance when subjected to peak demand (for example, a packet switch's processing delay can depend on the specific contents and type of each packet as well as its order of arrival).

- Mobile packet radio networks – Specific support for mobile nodes.

- Satellite networks – Specific support for satellite nodes.

- C3I and tactical networks – Support for diverse link technologies; modeling of adaptive protocols and algorithms; notification of network component outages and recoveries; scripted and/or stochastic modeling of threats; radio link models support determination of friendly interference and jamming.

As a practical example, the U.S. Army is using the commercial OPNET software to model and simulate the first-digitized-force systems architecture; a digitized division using Mobile Subscriber Equipment (MSE) with high capacity line-of-sight radios and asynchronous transfer mode switches. Using state-of-the-art computer hardware and software, OPNET is identifying and analyzing capabilities and limitations of different architectures and communications systems.

VI CONCLUSION AND RECOMMENDATIONS

The previous chapters discussed planning methods and software tools available to C4I system integrators when planning tactical communication information systems. This case study examined the utility of the interim joint standard – TNAPS+ - to plan a theater-level command and control system support plan based on Exercise Tandem Thrust-97. In addition, other automated software tools (i.e., SPEED, JITC-JIT, and OPNET) were described and their capabilities delineated. This chapter presents a conclusion and provides recommendations for further study in the area of tactical systems network planning and assessment.

A. CONCLUSION

This thesis gave an overview of planning tactical C4I systems using manual methods and automating the process by the use of software tools, specifically TNAPS+. Manual methods of estimating requirements and developing network architectures have normally been the process by which a systems integrator accomplishes this task; but as the military discovered during Desert Shield and Desert Storm, automating the planning and integration efforts will be crucial to operational success based on the projected size and complexity of future military networks. The development of communication equipment databases incorporating military and commercial components information, and user-friendly Graphical User Interface (GUI) for software programs provides easy access to technical configuration parameters and network drawing capabilities at the network and nodal levels.

TNAPS+ version 3.2 is an automated software-planning tool and modified by the Air Force's Electronic Systems Command, derived from an Army Signal Center program. It is the only software product available today that incorporates both military and commercial equipment databases for network architecture planning purposes. The thesis

produced extracts of planning templates derived from TNAPS+ for circuit, message, transmission and data networks, based on real exercise user requirements and transmission paths established for Exercise Tandem Thrust-97.

TNAPS+ is a powerful tool with many excellent features as outlined in the thesis. But several major deficiencies become readily apparent to the user. First, the TNAPS+ software is in a maintenance mode, meaning that the Air Force will not upgrade or modify the software unless a user sponsors the modification request with appropriate funding. As communications equipment changes over time, the equipment databases will quickly become dated. Second, the software does not offer a network modeling or assessment tool in real time or in a testing environment. Third and most importantly, TNAPS+ cannot be used in a collaborative environment; the software requires serial development of the architectural templates and planning documents. In today's world of complex networking and operational tempo, this shortcoming severely hampers the J6 staff's ability to plan concurrently. However, TNAPS+ is the joint standard and is used at the other military services' Command and Control courses in their network planning subcourses; therefore, its use as a network planning tool should continue until the Joint Staff identifies either another software product or the Joint Network Management System program provides a suitable replacement.

B. RECOMMENDATIONS

Many advances are being made in the development of architectural planning products that enhance the development and assessment of tactical communications. Along with TNAPS+, software tools such as the Marines' proprietary SPEED program, the Joint Interoperability Test Center's Interoperability Tool, and - the most promising tool of all – OPNET, are available today for use by the C4I systems planner. The required capability is to plan an evolving network architecture and to estimate traffic loading and overall network performance, capabilities that TNAPS+ does not currently offer. It is

recommended that follow-on studies by other C4I students be conducted on how to combine the operational planning utility of TNAPS+ with network assessment type capabilities of OPNET. Only when both types of capabilities are used will the C4I systems planner have an accurate picture and system assessment of the tactical C4I systems plan and the ability to modify the network as required based on system performance analysis. Other areas of research include the utility of the future Joint Network Management System program. This joint program offers abundant opportunities for application studies analysis at Naval Postgraduate School and in the C4I curriculum in particular.

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8. MIL 3, OPNET Planner, http://www.mil3.com/products

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